Compact Fluorescent Lamp Recycling Project Phase I Draft Report

Background Research and Program Options

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Executive Summary

This report is the Phase I report of the Compact Fluorescent Lamp (CFL) Recycling Project. The CFL Recycling Project is a three phase process to design a CFL recycling program and run a pilot project based on the design. Phase I of the project has included researching the number of CFLs recently sold, the methods of collection and payment, and how other fluorescent light recycling programs operate in order to identify options for the Phase II discussions. This information is presented in the following report. In Phase II a group of stakeholders will use the information in this report to discuss and design a pilot project for Oregon. Phase III will be the implementation and operation of the pilot project. It is expected that the pilot project will lead to a sustained CFL recycling program in the Northwest.

CFLs contain a small concentration of mercury. Mercury can be found in its elemental state or combined with other elements to make forms such as methylmercury. Mercury is transported in the environment through the atmosphere and hydrological cycles. Its is most frequently deposited in the soil or in bodies of water. Mercury is a persistent bioacumulative toxin. It is a neurotoxin and that has particularly strong affects fetuses and children.

Compact fluorescent lamps operate by energizing the mercury in the lamp, which then gives off ultraviolet radiation that causes phosphorus on the inside of the glass tube to glow. Fluorescent lamps require a ballast to regulate the current that the lamp receives. Materials in a CFL include glass, phosphorus, mercury, argon, plastic ballast casing and an electronic ballast circuit board.

Mercury can be emitted during different stages on fluorescent lamp disposal. An EPA report on mercury emissions from fluorescent lamp disposal indicate the percentage of total mercury released from the following disposal options: municipal waste landfill 3.2%, recycling 3%, municipal waste incineration 17.55% and hazardous waste disposal 0.2%. In Oregon CFLs are considered hazardous waste if they are generated by a business and fail the toxicity characteristic leaching procedure test of does not exceed 0.2 milligrams of mercury per liter. CFLs generated by households are not classified as hazardous waste.

Over 8.4 million CFLs were distributed in the Northwest during 2001. These were distributed through utility coupon program, retail sales and CFL giveaway programs. Sales in the previous 4 years ranged from 160,000 to 500,000 per year. In 2002, 2.5 million CFLs are projected to be sold. Estimates for future years are that 1 million lamps will be sold per year.

Currently, a large majority of household CFLs are going to municipal solid waste. Household hazardous waste collection in Oregon has been collecting less than 1,000 CFLs per year for recycling during the past year. Estimates developed for this report are that nearly 1.5 million bulbs will burn out in 2002 in the Northwest. The largest number

of CFLs expected to burn out in one year is 2.5 million in 2007, and after that point it is expected to decline to reach a steady rate of 1 million burn outs per year by 2009.

There are programs in Minnesota and Indiana that collect fluorescent lamps from households for recycling. These programs are the largest fluorescent lamp collection programs in the US. They both have retail store partners that collect the lamps from the public and store them until they are picked up for recycling. The program in Minnesota is funded mainly by Xcel Energy, an electric utility in the region. The program in Indiana is funded by the state and the local waste districts that participate in the program.

CFL collection options outlined in this report are retail collection, curbside recycling collection, household waste collection and a mail return collection. Several payment models are also outlined to describe the transfer of funds to pay for the recycling of CFLs. Recycling costs for the CFLs in the Northwest are expected to peak in 2007. Depending upon the cost per lamp of recycling and the percentage of lamps collected the cost ranges from $250,000 to $1.5 million that year. In the long term, the cost ranges from $100,000 to $600,000 per year.

MERCURY BACKGROUND

The central issue about CFL disposal is that they contain mercury. Mercury is a naturally occurring element. At standard temperature and pressure it is a silver colored liquid. There is concern about mercury because it is toxic to humans, bioaccumulative and very persistent in the environment. Most of the mercury on Earth is contained in ores and rocks underground. The largest repository on the surface is ocean sediment. Natural processes such as mercury volatilization from aquatic environments, volcanoes and geothermal activity are the primary non-anthropogenic sources of mercury emission. Humans have been producing mercury from cinnabar ore, or mercury sulfide, for hundreds of years. Anthropogenic mercury emissions are predominantly from fuel combustion and industrial processes. Estimates of the anthropogenic emissions in total global mercury emissions range from 40 to 75%.

Forms of Mercury

Mercury can take different forms in the environment. It is most often found in its elemental state Hg(0). Divalent mercury, Hg(II), may form compounds with inorganic anions. It may also bond with a methyl group (CH3) to form mono- or dimethylmercury. The transportation of mercury in the environment depends on which species of mercury is involved. Sources of mercury to the air include gaseous elemental mercury and mercury compounds and particulate mercury compounds. Elemental mercury can reside in the atmosphere for one to two years, while divalent mercury compounds reside there on the order of hours to months. Hg(0) can travel further from its emission source and is therefore spread more evenly throughout the atmosphere.

When mercury is in the methylmercury form, it is more available to aquatic organisms, and it appears that methylation is the primary pathway for mercury to enter the food chain. Mercury becomes methlyated mainly through aquatic bacteria. This means that methylmercury is most commonly found in aquatic environments, though non-biotic processes can also cause its formation. Methylmercury is easily absorbed by organisms and is bioacumulative. Long-lived fish high on the food chain typically have the highest concentrations of mercury in aquatic environments. Methylmercury comprises nearly 100% of all mercury forms found in fish tissues. Mercury in the oceans behaves much the same way as in freshwater. Monomethlymercury formed in the ocean is a primary concern from the human health perspective.

Mercury Transportation and Fate

Mercury in the Atmosphere

Hg (II) in both particulate and gaseous forms is removed from the atmosphere by either wet or dry deposition to the surface. Wet deposition involves Hg(II) being deposited by precipitation after interacting with water in the atmosphere. Gaseous Hg(II) is removed more effectively by both wet and dry deposition than particulate Hg(II). Hg(0) has a high vapor pressure and low water solubility and is not thought to take part in either wet or dry deposition directly. The main pathway for Hg(0) to be deposited appears to be through a reduction of Hg(0) by ozone into Hg(II). Overall, the deposition of Hg(II) is higher in proximity to mercury emission sources, while the deposition of Hg(0) involves greater transportation followed by deposition. Even after deposition in water, Hg(II) can still be reduced to Hg(0), volatilized and re-emitted.

Mercury on Land

On land, mercury is predominantly found as Hg(II) and forms various inorganic compounds. Approximately 1-3% of mercury in soil is methyl mercury, with the remaining fraction being other Hg(II) compounds. A small amount of Hg(0) will still be found in soil. The mercury in soil is not mobile and is not susceptible to extraction from the soil by water. Mercury in soil is subject to becoming sediment in water. The deposition of mercury to soil far exceeds the amount leached from soil, making land a mercury sink. Uptake by animals and plants of atmospheric and soil-based mercury is thought to be insignificant compared with other pathways.

Mercury in Aquatic Environments

Mercury can enter water through several pathways. The primary ones are deposition from the atmosphere, runoff from soil erosion and leaching from groundwater. The mercury that enters the water is typically Hg(II) and will end up either suspended in the water, in the sediment of the water body or in the life forms within the water body. 25-60% of the Hg(II) is attached to particulates suspended in the water, with the remaining fraction being dissolved in the water itself. Typically about 10% of the mercury in water exists as methylmercury. Mercury in an aquatic environment can remain in the water, settle into the sediment, get taken up by aquatic organisms or be volatilized and re-released into the atmosphere.

Mercury Toxicology

Mercury is a highly toxic element. It is a neurotoxin that affects the way that nerve cells function, and can also affect the brain, kidneys and lungs. Common symptoms of mercury poisoning include impaired vision, hearing and motor functions as well as personality changes, depression and an inability to concentrate. Severe poisoning can result in death. Children and fetuses are more susceptible to mercury poisoning because their nervous system and brain are still in development. The species of mercury that is Absorbed has a large affect on how it affects an organism, as does the manner in which it is absorbed.

Human Toxicology

Biological organisms do not readily absorb elemental mercury. Less than 0.01% of ingested elemental mercury is absorbed, and figures for absorption through skin is similarly low. The most effective absorption occurs through inhalation of mercury vapor, where 80% is absorbed through the lungs. Elemental mercury diffuses from the lungs into the blood and passes easily through the blood brain barrier. In the blood and in organs like the brain, Hg(0) is converted to Hg(II), which readily bonds with sulfur in proteins and enzymes. This disrupts their normal functioning. Mercury is excreted slowly and it takes 60 days for the body burden to drop by half. In cases of chronic mercury exposure the body usually reaches an equilibrium between the mercury being inhaled and the mercury being excreted. If the exposure is ended, all but the most severely poisoned individuals will see symptoms eliminated after several months.

Acute poisoning by elemental mercury can result in pneumonotis (lung inflammation). Chronic exposure to high levels of mercury can result in kidney damage, brain and neurological damage leading to tremors and personality disorders and lesions to the mouth and gums. Chronic exposure to lower concentrations can cause mild tremors, irritability, disturbed sleep and other brain and neurological disorders.

Methylmercury is the more toxic form of mercury because it is readily absorbed. It is estimated that methylmercury can have up to a 95% absorption rate for humans. Methylmercury readily penetrates the blood brain barrier and is found in high concentrations in the brain. Neurological effects from methlymercury poisoning are more pronounced than they are from inorganic mercury poisoning. It takes approximately 70-80 days for the burden of methlymercury in the body to drop by half after exposure has ceased. The effects of mild methylmercury poisoning include prickling sensations, parathesia, malaise, and blurred vision. Acute poisoning effects include irreversible tunnel vision, deafness, dysarthria, ataxia and possibly death.

As mentioned, mercury poisoning strongly affects fetuses and developing children. Both methyl and inorganic mercury are able to pass through the placenta and are found in breast milk. Developmental problems associated with mercury poisoning include delayed onsets of walking and talking, cerebral palsy, and impaired memory and attention span.

Levels of mercury poisoning that affect fetuses are low enough that the mother may have no symptoms at all.

Ecological Toxicity
Mercury also has effects on the broader ecosystem. Mercury is an ecotoxin that is a mutagen, a substance that increases the frequency of mutations, and teratogen, an agent that causes the malformation of an embryo of fetus. Mercury has no known beneficial biological functions. As mentioned before, mercury does bioacumulate up the food chain which means higher exposure on the upper trophic levels of an ecosystem contaminated with mercury. Due to this biomagnification, very small concentrations of mercury in water can lead to dangerously high body burdens of mercury in the large predators of a lake ecosystem. Estimations show that mercury in water at concentrations of 1 ppt can lead to large a medium size fish with body burdens of 1-10 ppm of mercury. Data kept by the EPA from the late 1980s-2001 for freshwater fish in the northeastern US show that several species have median mercury concentration over 0.5 ppm. As with humans, methylmercury is more toxic and more readily absorbed by organisms than is inorganic mercury. Organisms in the early stage of development are likewise more susceptible to mercury poisoning.

In aquatic invertebrate populations a concentration of 1 ppm is enough to cause affects. Aquatic flatworms regenerated body parts with gross abnormalities and the heart rate rhythms of freshwater crabs was severely affected. Mercury toxicity to fish has been well studied because they are a frequent pathway of mercury to humans. Generally, chronic exposure to mercury has been shown to affect reproduction, growth, behavior, metabolism and blood chemistry in marine and freshwater fish. Birds are exposed to methylmercury mainly through their piscivorous, or fish eating, diet. Concentrations of 0.5 to 6 ppm in bird eggs can result in decreased weight, malformations, lowered hatchability and altered behavior. Studies on larger mammals have not been as conclusive in showing negative impacts from mercury, but Florida panthers have been found to have levels high enough to cause toxic affects. Increased body burdens of mercury have been noted in seals, otters, mink and polar bears.

HOW COMPACT FLUORESCENT LAMPS WORK

Fluorescent lamps, whether they are tubes or compact, give off light by the process of fluorescence. The standard parts of a fluorescent lamp are the tube, the electronics at the end caps and the ballast. The tube is a glass cylinder that is coated with a layer of phosphorus on the inside. The tube is filled with an inert gas, typically argon, and a small amount of elemental mercury in a liquid form. The contents of the tube are kept under very low pressure. At the end of each tube is an electrode that is connected to the pins on the lamp’s outside. The electrodes on each end are usually made of tungsten wire and are coated with a material that gives off electrons when a current runs through the electrode. The ballast regulates the flow of the current through the electrodes both at startup and during normal operation of the lamp. Older ballasts were typically a magnetic inductor housed in the lamp fixture. For CFLs, the ballast is electronic and typically attached to the tube. The base of the tube contains the ballast that regulates the flow of current to the bulb. The components of common CFL ballasts are an electronic circuit board, a plastic housing and a metal screw base that fits into light sockets.

When the lamp is first turned on the electrodes ‘boil off’ electrons from their coating materials. These electrons flow across the tube and ionize the gas, creating an electric arc across the tube. The energy of the arc in the tube changes the mercury inside from a liquid to a gas. As the mercury gas collides with the electrons and ions in the tube it become more energized. When the mercury electrons drop back to the initial lower energy state they emit ultraviolet radiation. The phosphorus coating on the inside of the tube then absorbs this ultraviolet radiation and re-emits the energy as visible light and a small amount of heat. Fluorescent lamps eventually fail when the emissive coating on the electrodes is depleted. This process causes the ends of tubes to blacken as they age.

This basic mechanism for producing light from fluorescence is the same that was used in the first fluorescent lamps in the 1930s. Over time though the bulbs have undergone changes. The part that has changed the most is the ballast. The basic function of the ballast is to regulate the flow of current to the lamp and to provide enough voltage to ionize the gas in the tube when it is started. The ionized gas inside the tube has very low electrical resistance and will draw enough current to damage the lamps components if it is not regulated. Early ballasts were basic wire coils around an iron core, and many of them contained polychlorinated biphenyls (PCBs) as insulators, though this practice was stopped in the early 1970s. Electronic ballasts are becoming the standard since they provide quicker starting times, less flicker, no audible hums and more efficient lamp operation. The materials that comprise an electronic ballast system are those that are the components of the circuit board and the plastic housing. Most CFLs sold today use electronic ballasts and Energy Star CFLs are required to have an electronic ballast.

Other significant improvements were made in fluorescent lamps. The phosphors that are being used now render a warmer light color and emit light more efficiently than did the ones in the past. The amount of mercury in the tubes also deceased significantly over time. The average 4-foot lamp made in 1995 contains 75% less mercury than one manufactured in 1985. CFLs typically contain between 4-8 mg of mercury, although there are some with higher or lower amounts.

The life span of a CFL is rated in hours. This number, called the rated life, for most CFLs is between 6,000 to 15,000 hours. The rated life means half the products in a test group will fail before reaching the rated life and half will operate past the rated life. The Energy Star guidelines state that Energy Star CFLs must have a rated life greater than or equal to 6,000 hours. Assuming that the average bulb is used 4 hours per day, a 6,000 hour rated bulb should last 4.10 years and a 10,000 hour bulb should last 6.85 years. To bring down the price and still be Energy Star compliant many CFL manufacturers have been selling more 6,000 hour bulbs.

It is difficult to determine an average burnout rate for CFLs. Products tested by the National Lighting Product Information Program (NLPIP) show a wide distribution of life times depending upon the cycles of the test. Energy Star requires rated lamp life to be tested by cycling through leaving them on for three hours followed by 20 minutes turned off. Scenarios where the time on is less than one hour followed by 5 or 10 minutes off decreased the life of lamps significantly.

The bulbs that were distributed through utility programs during the past year were required to be Energy Star compliant. This is helpful in determining the specifications of a vast majority of the bulbs that will need to be recycled in the coming years.

CFL DISPOSAL AND MERCURY RELEASE

When fluorescent lamps reach the end of their life, they are disposed typically in a regular municipal waste landfill, a hazardous waste landfill or at a lamp recycling facility. During the process of disposal some of the mercury in the lamp can be emitted to the environment. The amount, type of mercury, and deposition of the emission depends upon what the method of disposal.

Mercury Emission from Disposal

The US EPA's Office of Solid Waste studied this issue in its 1997 report "Mercury Emissions from the Disposal of Fluorescent Lamps." The purpose of the study was to determine the waste management policy that would lead to the least amount of mercury being emitted to the environment. Table 1 summarizes the percentage of mercury emissions for each disposal option. The study addressed the disposal of fluorescent tubes. No studies were found that specifically addressed the disposal of CFLs. It seems reasonable to use the findings of the EPA study for CFLs since they operate in the same manner as tubes. Primary differences to note are that CFLs contain about 1/6 to 1/3 the amount of mercury in the tubes in the study and that the mercury may deposit differently on the components of CFLs than on the end caps of tubes.

The report assumes that at the end of life some of the mercury in the bulb is in vapor phase, some is incorporated into the phosphor powder and some is combined with the glass and end caps of the bulb. The mercury in vapor form is elemental mercury, while the remaining mercury is divalent, or Hg (II). The report consistently assumes that mercury vapor accounts for 0.2% of the total amount of mercury in the lamp at the end of life. It also assumes that the mercury in the glass and end caps will not be emitted to the environment without being heated. For each disposal option the report has a high estimate, low estimate and central estimate of the amount of mercury emitted.

Central Estimates of Mercury Emissions	Elemental	Divalent
MSW and Similar Transport	100%	2.80%
Transport to HW site and Recycling facilities	1%	0.03%
Drum top crushing machines	10%	2.80%
Recycling	10%	3%
Municipal Waste Combustion	0%	15%
Municipal Waste Landfill	100%	0.20%

Table 1 – Summary of mercury emissions per lamp based on disposal activity

The first phase of disposal analyzed is emissions from transportation from the point of generation to the final destination, either a landfill or a recycler. The report cites three different sources reviewed for emission estimates. The average estimate based on research done for National Electronics Manufacturers Association (NEMA), Electric Power research Institute (EPRI) and the US EPA is that 3% of the mercury in a bulb is released when it is broken. All bulbs are assumed to break during transportation to a municipal solid waste (MSW), or Subtitle D landfill, which means that 100% of the elemental mercury vapor is emitted and 2.8% of the divalent mercury in the phosphor powder is emitted. During transport to hazardous waste facilities, known as Subtitle C facilities, and recyclers the breakage rate is assumed to be much less due to better bulb packaging. For the central estimate of emissions during transportation to hazardous waste or recycling a breakage rate of 1% was used. This indicates that 1% of the elemental mercury vapor is emitted and 0.03% of the divalent mercury is emitted. Overall, less than 0.03% of the total mercury in lamps shipped to hazardous waste or recycling facilities is emitted during transportation.

Prior to transportation some lamps are processed by a drum top crusher. These devices crush fluorescent lamps before they are transported to their final destination. These crushers use negative pressure and have varying degrees of control effectiveness for capturing the mercury from crushed tubes. The report used a 90% control rate for the mercury vapor from the bulbs. The mercury in the phosphor powder and end caps is assumed to be under no greater control than for normal broken lamps because negative pressure is only present when the crusher is operating. The openings in crushers can act as emission points for mercury contained in the phosphor powder and other parts of the lamp. It is calculated that 10% of the elemental mercury vapor is emitted and 2.8% of the divalent mercury is emitted. This reaches a total of 2.82% emission of overall mercury in drum top crushing.

There are additional emissions related to the recycling of fluorescent lamps. The recycling of lamps is divided into primary and secondary recycling. Primary recycling includes the crushing and separating of lamps and the retort and recovery of mercury. Secondary recycling refers to the recycling of end caps and glass from the lamps. Of the total mercury entering the recycling facility it is estimated that 3% is emitted during primary and secondary recycling. The larger fraction of the emitted mercury occurs during the secondary recycling. The central estimates calculated in the report are that 10% of the elemental mercury vapor and 3% of the divalent mercury is emitted during recycling.

Municipal waste incinerators are one further option for disposal. The report assumes that all of the elemental mercury vapor will be emitted prior to reaching the incinerator so no elemental mercury will be emitted during incineration. For the calculations it was assumed that the emission controls on the incinerator would capture 80% of emissions. The final central estimate is that no elemental mercury and 15% of the divalent mercury that enter a waste incinerator will be emitted.

Placing fluorescent lamps in a landfill is the last option considered in the report. The report assumes that all of the elemental mercury in the lamps is emitted by breakage in transit to or at the landfill. The emission rates for the remaining mercury bound in the end caps and phosphorus in the tube are based on a test that placed bulbs under a half foot of soil and 1 foot of soil. After 20 days 0.8% and 0.2% of the mercury, respectively, was released to the air through evaporation. The final estimate of the report is that 100% of elemental mercury vapor and 0.2% of divalent mercury is released from municipal solid waste landfills. The report estimated that for hazardous waste landfills 100% of elemental mercury is emitted for the same reason as above and that 0% of the remaining mercury is emitted because the waste is stabilized after arriving at the landfill.

Table 2 shows the total amount of mercury emitted from disposal of a lamp with 5 mg of mercury. The calculations are based on the emissions estimates from Table 1. The emissions from transportation are subtracted from the original amount of mercury to find the amount of mercury entering the final deposition phase.

Emissions From Transportation	**Elemental**	**Divalent**	**Total**
Regular transport	0.01	0.14	0.15
HW, Recycling transport	0.00	0.00	0.00
Emissions from Final Deposition	**Elemental**	**Divalent**	**Total**
Subtitle D MSW landfill	0.00	0.01	0.01
Recycling	0.00	0.15	0.15
Municipal waste incinerator	0.00	0.73	0.73
Subtitle C landfill	0.01	0.00	0.01
Total Emissions	**Total (mg)**	**Total (%)**	
Regular Transport and Subtitle D MSW landfill	0.16	3.19	
Recycling Transport and Recycling	0.15	3.06	
Regular Transport and Municipal waste incinerator	0.88	17.55	
HW transport and Subtitle C landfill	0.01	0.22	

Table 2 – Mercury emissions estimates in mg from a lamp with 5mg of mercury

The long term emissions of mercury from landfills was the subject of a recent study by a Oak Ridge National Laboratory scientist. Methylmercury was found in the water vapor that condensed out of the gas emanating from a Florida landfill. Concentrations were at least 100 times those typically seen in water. In the August *Atmospheric Environment*, they report finding some 50 nanograms of dimethyl mercury per cubic meter of landfill gas. (http://www.sciencenews.org/20010707/fob1.asp). Mercury can also escape from landfills through leachate. A study by the Research Triangle Institute showed that the average mercury concentration in landfill leachate is .0008 mg/L.

CFL Recycling

There are many companies across the US that recycle fluorescent lamps. This section will focus on the process they use. As with many fluorescent lamp issues, CFLs are analogous to regular fluorescent tubes. The differences between the two as they relate to recycling will be discussed after the process description.

Fluorescent tube recyclers use a large machine to process the lamps that they receive. When lamps are received they are typically in a long container that keeps the tubes intact or in a box or drum if they are CFLs. The lamps are fed into an open chute in the machine. The lamps are crushed once they reach the end of the chute. The area where the lamps are crushed is under negative pressure so that a carbon filter device captures gas and particulates from the crushed lamp. After the initial breakage, the phosphor powder, which contains much of the remaining mercury, is pulled from the glass and other components by a vacuum and stored in a sealed metal drum. The crushed components then move down a conveyor line where the smaller pieces of broken glass are separated and fall out into a drum and the remaining larger components are left to fall into another drum at the end of the conveyor.

Many lamp recycling operations consist only of the machine that separates these materials and safely contains the mercury. Once the glass, metal and mercury bearing phosphor are separated they are sent for secondary recycling. The metal is mostly aluminum and is recycled in secondary aluminum operations. The glass is often used as an aggregate in concrete, fiberglass or road products.

The mercury bearing phosphor powder is processed by a facility that has a retorting device. Some lamp processing facilities are able to retort on site. The retorting machine consists of a vacuum heating unit and a distillation and condensation system that separates the mercury from other substances. The retorting process results in semi-pure metallic mercury and other separated materials that are non-hazardous waste. The mercury may be further refined in a triple distillation process that uses vacuum distillation to remove traces of impurities and allow the mercury to be sold as pure technical grade mercury.

CFLs differ in physical construction from fluorescent tubes. The major difference is that the ballast is integrated on most CFLs. The ballasts for fluorescent tubes are in the lamp fixture and do not get replaced. Lamp recyclers have not developed a standard way of dealing with the CFL ballasts. The recycling machine does damage the end caps and ballasts that are fed through, but they appear to remain mostly intact. Two recyclers that serve the northwest are currently letting the ballasts fall into the metal bin at the end of the machine, where they are then shipped off to the metal recycler. These recyclers stated that they do not know how the ballasts are processed after they leave their facility. A lamp recycler in Minnesota, Mercury Technologies, has been manually separating the plastic ballast case and removing the electronic circuit boards after the lamps have been processed. The electronics are being sent to a recycler that handles electronic products and reclaims the metals. The plastic is being sold to a facility that ultimately burns it for fuel.

CFLs pose an interesting question in relation to breakage during transportation. It is reasonable to assume 100% breakage for CFLs being sent to landfill for the same reasons above. Tubes that are sent to recyclers are packaged in boxes that are designed to keep them in tact. The recyclers interviewed so far have received CFLs in regular boxes supplied by the lamp generator or in drums. They do not seem to be as well packaged as the tubes and the recycler EcoLights Northwest in Seattle and Mercury Technologies report that there are often broken lamps in the boxes. The boxes and drums do not appear to be under any emission control devices while they are waiting to be recycled. Based on these examples, it is possible that CFLs have a higher percentage of broken bulbs in transport and while being stored for recycling.

The cost of CFL recycling may eventually fall as the technology to recycle CFLs improves and the volume increases. Currently CFLs constitute a small part of lamp recycler business. CFLs are comparatively more expensive to recycle than fluorescent tubes. The standard cost for recycling a CFL ranges between $0.35 and $1.00, while the cost for a 4-foot fluorescent tube is $0.40. Part of the extra cost is that CFL are more labor intensive to handle and recycle. EcoLights Northwest said that if they receive more CFLs they will look into developing a more automated handling system, which would consequently drive down prices.

REGULATION OF CFLs

Waste CFLs usually fall into the regulation of mercury containing waste lamps. There are some fluorescent bulbs in use that have low mercury content. These bulbs may be treated as solid waste if the manufacturer provides documentation that the bulb does exhibit hazardous waste characteristics or if the leachate from the Toxicity Characteristic Leaching Procedure (TCLP) does not exceed 0.2 milligrams per liter. The CFL recycling program being explored is concerned with the collection and recycling of CFLs generated by households. Because all CFLs contain mercury, the goal is to recycle them regardless of whether they fail or pass the TCLP. Given that there may be program partners for whom waste lamp regulations may apply, both household and business regulation will be discussed.

People who generate mercury-containing lamps in Oregon have several options for disposal of lamps. There are no regulations regarding the disposal of household CFLs as solid waste. This means that households can dispose of fluorescent bulbs in their weekly garbage collection. Local waste authorities however may limit the amount that one household may dispose of each week. Metro, for example, will not allow a household to dispose of more than 25 fluorescent bulbs in one collection. A household who disposes of more than 25 can either arrange to take them to the Metro hazardous waste facilities, or take them to a local fluorescent bulb recycler. The major Metro transfer station in northwest Portland will take small amounts of fluorescent bulbs free of charge from individual households. These bulbs are collected and sent to a local fluorescent bulb recycler.

Businesses that generate fluorescent bulb waste face different management requirements. A business that is a conditionally exempt generator (CEG) may dispose of fluorescent bulbs in the solid waste landfill, if allowed by the landfill operator. A conditionally exempt generator produces less than 220 pounds of hazardous waste, including fluorescent bulbs, each month and does not accumulate more than 2200 pounds at one time. Conditionally exempt generators are subject to the rules of local waste authorities, such as Metro's limit of 25 fluorescent bulbs per solid waste load. If they do have a large load, conditionally exempt generators can take their fluorescent bulbs to the Metro transfer station to be collected for recycling, but they must make prior arrangements and must pay a fee to Metro. They are encouraged to make private arrangements with local fluorescent bulb recyclers to handle their fluorescent bulbs.

Oregon allows fluorescent bulbs to be managed under the Universal Waste Rule, which encourages the collection and proper disposal of certain hazardous wastes by streamlining the regulation and handling requirements for them. A Universal Waste handler is a person who generates or receives universal waste for the purpose of consolidation. Small quantity universal waste handlers are those that have less than 11,000 pounds of universal waste at any one time while large quantity handlers have more than. Fluorescent bulbs are classified as universal waste and waste lamps must be sent to a universal waste destination facility for recycling or disposal. Handlers that generate universal waste may keep the fluorescent bulbs on site for one year, unless they can demonstrate that more time is needed to generate quantities needed for proper recovery or disposal. Handlers that receive fluorescent bulbs from off site and accumulate more than 2,200 pounds cannot keep the universal waste for longer than 6 months without permission from Oregon Department of Environmental Quality. They must also keep records of waste collection and submit written evidence that they are in compliance with the universal waste rule to the DEQ.

When fluorescent lamps are shipped away from the generator they must be sent to another universal waste handler or to a universal waste destination facility. All universal waste shipments must meet packaging, labeling, placarding and shipping requirements for state and federal transportation requirements. The federal universal waste rule does not consider universal waste to be hazardous waste unless it falls under any other Department of Transportation hazard classes. Small quantity universal waste handlers do not need to keep records of their shipments, but are encouraged to do so. Large quantity universal waste handlers are required to keep records of each shipment sent off site. Universal waste handlers that accept more than 2,200 pounds of universal waste from offsite have to keep records of the shipment off site and can only ship it to a universal waste destination facility. When the bulbs are disposed of, they are ultimately subject to hazardous waste requirements. Destination facilities include hazardous waste landfills and lamp recycling facilities. Management of fluorescent lamps under the universal waste rule is optional for lamps generated by conditionally exempt generators and households.

CFL SALES DATA

CFL sales have grown dramatically over the past few years, especially in the northwest region. Much of this is attributed to recent energy problems and the programs of utilities to distribute for free or provide coupons for the sale of CFLs. The Northwest Energy Efficiency Alliance (NEEA) has been instrumental in promoting CFLs from the utility side and have kept track of CFL sales over the past years. Their numbers are from the sales of CFLs by over 1,400 retailers in the Northwest with whom NEEA works. The numbers are presented in Table 3. Fixtures are compact fluorescent lights that consist of the tube and contact pins only and plug into separate ballast.

Previous Years CFL Sales in the Northwest				
	1997	1998	1999	2000
CFLs	204,000	160,830	255,031	528,159
Fixtures		76,393	69,400	50,822
Total	204,000	237,223	324,431	578,980

Table 3 – CFL sales from NEEA

2001 was the year that the utility programs were implemented. The numbers in Table 4 are provided by EcoNorthwest, a consulting firm, who had tracked both sales and giveaway programs from the 4th quarter of 2000 through the 4th quarter of 2001. The major utility programs are shown separately. The numbers for the individual states in the coupon and non-coupon sales categories are based on the totals for the entire region distributed over the population of each state.

CFL Distribution - Q4 2000-Q4 2001				
Distribution Source	**Total**	**OR**	**WA**	**ID**
Non-Coupon Sales	4,200,976	1,353,148	2,333,119	514,709
PGE Coupon Sales	1,750,000	1,750,000		
PacifiCorp Distribution	799,007	608,713	190,294	
Coupon Sales (excluding PGE)	889,570			
King County Giveaway	412,350		412,350	
Other Giveaway Programs	402,900	52,000	312,900	38,000
TOTAL	8,454,803	3,763,861	3,248,663	552,709

Table 4 – 2001 sales, coupon and distribution program data for the northwest

NEEA has made forecasts for the future sales of CFLs. Retail sales are likely to be the primary distribution outlet for CFLs unless the utilities decide to do another promotion. For 2002, NEEA expects that 2,500,000 CFLs will be sold in the region. For each year after that CFL sales are expected to remain steady at 1,000,000 per year.

It is difficult to predict the life span of CFLs because there are many factors that vary across the millions of CFLs that have recently been distributed. Among these factors are the rated life, product manufacturer and location and usage of the lamp. No definitive data could be found that showed the failure rate of CFLs over a number of years. Data from CFL testing by the NLPIP shows a wide range of failure rates for different usage situations from which few generalizations could be drawn. Nearly all of the CFLs distributed or sold recently have been energy star compliant, which means that they have a minimum rated life of 6,000 hours. As noted earlier, this is the number of hours at which half of a sample population will fail. If we assume an average use of 4 hours per day, the rated should be 4.10 years. It is frequently cited that the upper life span of CFLs is around seven years.

The forecast in Figure 1 relies on the above figures and assumes that half the CFLs sold in a given year will fail within 4 years and that all will fail by 7 years. The actual numbers estimated are presented in Appendix A. It is assumed that there is a linear failure rate of 12.5% for the first 4 years and another linear failure rate of 16.66% for the last three years. These failure estimates were applied to the actual sales data given by NEEA and EcoNorthwest and the forecast supplied by NEEA to arrive at the numbers in the figure below. The forecast does not take into account any CFLs sold before 1997. It should be noted that this forecast is based only on the assumptions above and does not reflect failure rates from any data source.

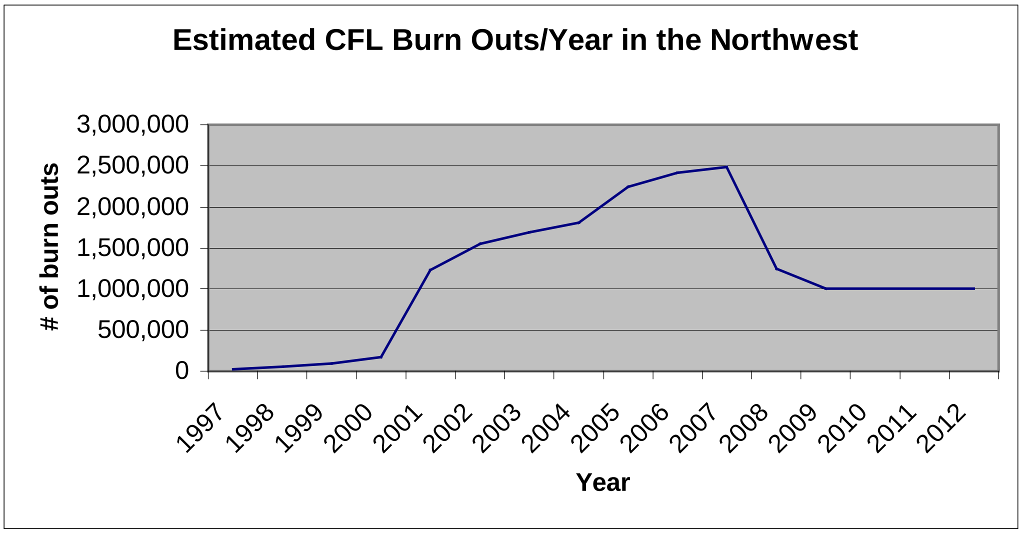


Figure 1- Estimated number of CFL failures per year for the Northwest

These numbers show the approximate number of CFLs that will need to be recycled each year. The highest number of CFLs that will need to be recycled comes in 2007 when it is expected that 2.5 million CFLs will fail. The number per year drops off rather quickly and reaches a steady state of 1 million failures per year by 2009. Even if the failure rates developed for this estimation are not entirely accurate, it is reasonable to assume that there will be a rise in CFL failures in the years following 2001 because of the high sales from that time. It is also reasonable to assume that the failures will reach a constant level as CFL sales reach a constant level.

CURRENT COLLECTION, RECYCLING AND DISPOSAL OF CFLS

The disposal options for failed CFLs depend upon the classification of the user. Hazardous waste generators are required to manage their CFLs as either universal or hazardous waste. Conditionally exempt generators may either dispose of them in a landfill or pay a lamp recycler or their local government to recycle them. Households have the option of either placing them in the municipal solid waste, taking them to a hazardous waste roundup or collection site, or taking them to a recycler that accepts them with or without a fee.

Three local governments that have permanent collection facilities to accept CFLs were asked how many CFLs they are taking in. These facilities only accept lamps generated by households. Metro's facilities have been taking in 50 CFLs every month over the last year. Salem's transfer station said that they sent 24 CFLs with their last recycling shipment, which they send off 3 to 4 times each year. Lane County said they sent 20 CFLs with their last shipment and they ship about as frequently as Salem. DEQ Household Hazardous waste events do not keep records of the amount of CFLs they collect. It is clear that a low number of CFLs are being recycled through household hazardous waste collection.

The lamp recyclers that serve the northwest are not receiving very many CFLs yet either. Earth Protections Services facility in Lake Oswego, Oregon, took in 7,442 CFLs in 2001. Environmental Protection Services in Brooks, Oregon reported that they recycled between 4,000 and 5,000 CFLs in 2001. EcoLights Northwest in Washington did not have an exact number but reported that they have received a few thousand CFLs in 2001. These companies said that a majority of the CFLs that they recycle currently are from businesses and property management companies.

The two major options for household generated CFLs are either recycling or sending it to the municipal solid waste. Based on the forecasting done in the last section, there could be over 1.25 million household generated bulbs in the northwest that failed in 2001. Even if the early burnout rate is overestimated, a significant portion of bulbs sold between 1997-1998 that should have failed by now. Given the numbers of bulbs currently being recycled it appears that nearly all the burnt out CFLs from households are going into solid waste disposal.

FLUORESCENT LAMP COLLECTION PROGRAM CASE STUDIES

In an earlier study, Zero Waste Alliance outlined the program structure of 4 fluorescent light recycling efforts. Two of these were simple municipal solid waste collection programs. The other two used collection points such as retail stores in conjunction with other program partners to recycle fluorescent lights. For the follow up case studies, we interviewed the recycling programs in Minnesota through Xcel Energy and in Allen County, Indiana. The follow up interviews were aimed at obtaining more specific information about how the programs began and developed.

Xcel Energy

Xcel's fluorescent lamp recycling program uses retail hardware stores as collection points for household CFLs. The program began in 1993 when Minnesota banned fluorescent lamps from their landfills. Initially after than ban was put in place there was concern about the lack of infrastructure to collect fluorescent lamps for recycling. The head of the Minnesota Pollution Control Agency (MCPA) contacted Mercury Technologies, a lamp recycler in Minnesota, about how they could best help build the infrastructure to recycle lamps in stores. Sue Yarrusso, President of Mercury Technologies, requested that the regulations for store or business collection be made as simple as possible. The MPCA wrote rules specifying that a store or business that stores less than 1,000 lamps for others at one time must file a notice with MCPA notifying them of the address where the lamps will be stored, how many lamps will be stored and how long they are intended to be stored. Stores that will store over 1,000 lamps face regulations similar to universal waste handlers that accept over 2,200 pounds of universal waste in Oregon.

After the streamlined rules were in place Mercury Technologies began the task of setting up retail store collection sites. Initially they did not find many hardware stores that were open to the idea of collecting lamps. Most were concerned about collecting other people's waste and the space that it would take. The utility co-operatives in the state were not open to setting up a collection program due to liability issues. Mercury Technologies continued to meet with hardware store owners, sometimes taking them out to dinner to discuss their proposal. Mercury Technologies found that the benefit that resonated most with storeowners was the potential increase in foot traffic in the store. They did not have any printed marketing materials that they used in their presentations to the stores. Yarusso said that it required a large investment of time to set up the relationships with the hardware stores. Today, Mercury Technologies works with over 200 hardware stores in Minnesota as fluorescent lamp collection points. The hardware stores in the program are comprised of either independent hardware stores or hardware stores that are franchised, such as Ace or True Value.

When Mercury Technologies does get a store to join the program they travel to the store to provide employee training on how to store the lamps, safety procedures and what to do in case a lamp breaks. Mercury Technologies provides each store with storage containers for 4 and 8 foot bulbs that are replaced whenever a pickup is made. CFLs are stored in a box of the store's choosing. The total collection area for each store is about four square feet. Mercury Technologies typically picks up lamps from each hardware store three or four times per year. The stores will call if they approach 1,000 lamps since that is maximum allowable by regulation. The Mercury Technologies truck will also provide additional training on site if needed when they make pick up calls.

The payment structure of the program is where Xcel is involved. Xcel must spend part of their rate base on conservation improvement programs and has chosen to sponsor the fluorescent lamp recycling done by Mercury Technologies. Each spring Xcel Energy mails or puts in the newspaper a sheet of 10 coupons for $0.50 off of the recycling fee charged by the hardware store. Households can then bring in their burnt out lamps and pay the stores recycling fee minus the coupon value. The store retains the coupon and it is picked up by Mercury Technologies. Mercury Technologies then invoices the store for the cost of the recycling minus the coupons redeemed. Xcel Energy is then invoiced for the value of the coupons. Mercury Technologies charges different rates for different bulbs, such as 50 cents for recycling a CFL without a ballast and 80 cents for recycling one with. The hardware stores are free to charge any price to the household that they want for recycling the lamps. Yarusso said that often times stores will waive the recycling fee if the customer buys a new bulb or will recycle it for free with the coupon. She noted that some stores also charge more than what it costs them to recycle the lamps.

The program has expanded to include collection by municipalities at waste collection sites. Ann Morse runs a county waste district in Minnesota that receives funds from Xcel for lamp recycling. The county accepts ten lamps per year from households and conditionally exempt generators for recycling. Because Xcel provides power to 75% of the county they pay 75% of the county's lamp recycling cost. Both Morse and Yarusso noted that many hardware stores seem interested in lamp recycling because most lamps are bought at retail stores. Providing the recycling service gives them a chance to increase their share of fluorescent lamp sales. Other small electric utilities are working with Mercury Technologies and duplicating what Xcel has done. Yarusso cautioned that the biggest problem would be finding a recycler that is willing to put the work into developing the relationships with the hardware stores and training them.

Allen County, Indiana

At the time of the initial case study, Allen County had a collection program with one Sears store in the county to recycle 4-foot fluorescent tubes generated by households free of charge. Stacie Perkowskie of the Allen County Waste Management District has been in charge of the program from its beginning. The program began as part of Indiana's mercury reduction effort started by their governor in 1998. The order put Indiana waste districts in charge of the reduction effort. The state government started a 4-year grant for this effort and the money was paid out based on the population of each district. They started out with a fully funded collection event to get as much mercury as possible collected up front. Allen County received $30,000 over 4 years, with half coming up front and half having to be spent by the districts and then reimbursed later. 75% of the disposal and advertising cost of the program is paid by the state funds and the districts pay 25%.

The process of engaging Sears began with the general manager of the local Sears store. Perkowskie and one of her managers presented the case for collecting lamps at the store and pointed out the good that it could do for the environment and for foot traffic in the store. The general manager agreed and went along with a pilot program for three months to see how it would go. The original Sears store in the program has now been involved for over three years. It helped that the Sears store was using the same mercury recycler for their bulbs, even though they don't package their bulbs with the household collection. Perkowskie limits the Sears store to having two pallets to minimize the risk for them. She furnishes all the boxes for them, which come from the lamp manufacturers. If there is a broken bulb then Sears is instructed to seal the ends of the box with tape. The workers also wear goggles and gloves when handling the tubes. When the bulbs are in transit to the recycler they shrink wrap the pallets to minimize leakage if the tubes break. The training of the dockworkers at Sears is done by Perkowskie with materials and resources provided by the mercury recycler. They have had good luck with the dockworkers in the store because they have had very low turnover. The recycler for the program was selected by a statewide RFP process and handles all the mercury waste for Indiana programs.

Perkowskie noted before that other retail chains such as Lowe's had expressed interest in joining the program, but that the county lacked the resources to monitor more than two stores.

In February of this year 10 Sears stores were added to the collection program in Indiana. Allen County had started with one Sears and had added another Sears store in the county, but the second store had to close due to cutbacks. The expansion is funded by a 2-year grant from the state for $40,000, half of which goes to pay the recycling expenses and half to pay advertising. Each waste district that has a participating Sears pays for half of the overall costs of the program.

The stores are backed by the corporate environmental division in Sears. The local general manager at the Sears store was the link to getting into Sears at the corporate level. Perkowskie and another employee met with the Sears corporate environmental division for a full day to pitch the program to them. Sears is interested in running the program in just Indiana for a while to monitor its success. Perkowskie noted that Sears is looking to expand this collection program in the near future and has asked her to keep track of recycling efforts she hears of. She offered to be on a conference call or help out our CFL collection program in any way that she can when our process gets going.

RECYCLING PROGRAM MODELS

A list of program models has been compiled from suggestions we have heard and what we have seen in other programs. These models are not an all-inclusive list of CFL collection or payment methods. It is intended to guide the discussion of the design for a pilot project.

Presented here are four ideas for collection programs: retail store collection, curbside collection, enhanced household hazardous waste collection and prepaid mailers. The chart on the following page shows an outline of each of the models. The participants listed in each table are the main partners in each collection system, but are not the only participants that would be involved with each collection system.

Options for CFL Collection

RETAIL COLLECTION

	Positives	**Negatives**
Retail	Potential increased foot traffic and higher CFL sales from customers who recycle their bulbs	Storing hazardous waste on site, collection area takes up floor space, extra employee time for training, taking and storing bulbs and dealing with any paperwork.
Customer	Many potential collection sites, combination trip with getting a new CFL eliminates special trip for recycling	Retail stores may not be accessible to everyone
Collectors/ Recyclers		Training of store employees in many locations, collection at many locations
Government	Does not have to regulate retail collection if there is no government involvement, relives collection at government HHW sites/collections	No regulation authority over the program

CURBSIDE PROGRAM

	Positives	**Negatives**
Waste Haulers	Potential revenue source from charging for collection	Transportation of hazardous waste, extra time to handle CFLs on collection routes, space on truck, breaking and packaging are potential problems.
Customers	Most convenient option, no explicit extra fee for disposal	Does not provide complete population coverage, forces payment on people who may not use CFLs, potential packaging/breaking issues
Collectors/ Recyclers	Centralized pickup, fewer trainings required than with retail	Extra transportation may result in more bulb breakage, possible extra packaging to process

Increased Utilization of Household Hazardous Waste Capacity

	Positives	**Negatives**
Government	No increased regulatory concerns, maybe only an increased awareness campaign	Increases costs to HHW collection sites and events
Customers	Presumably free collection, collection centers near most population centers, events occur statewide	Inconvenient trip to HHW collection site, infrequent collection event require storage of burnt out CFLs
Collectors/ Recyclers	Utilizes existing contracts/arrangements, little/no training of HHW professionals	

Mail-in Collection

	Positives	**Negatives**
Customers	Very convenient, does not require a special trip	Getting mailer, any packaging
Government		Shipping breakable, PBT bearing objects by mail
Collectors/ Recyclers	Presumably eliminates pickup costs	Labor required to unpackage CFLs
Others		Waste from packaging and sending each bulb

Retail store collection has several aspects that make it an attractive option. It is a proven model that has worked in other states and may work in the northwest as well. One positive factor is that retail stores have a presence for almost all residents. This allows for many collection points in rural areas and for multiple collection sites in more urbanized areas. Another positive factor is that recycling of a CFL would not require a special single purpose trip to a recycling facility. The recycling of a CFL could be combined with a normal visit to a retail site. One related benefit is that retail collection offers a link between disposing of an CFL and purchasing a new one. This is convenient for the customer and allows for payment methods such as a credit or deposit system towards a new CFL, such as some Minnesota stores offer. Retail stores may also see a benefit to recycling CFLs in increased foot traffic and a good environmental image in the community.

Retail store collection has difficulties associated with it as well. The major obstacle is that retailers may not be interested in being involved with the collection of people's waste. CFL collection would require floor space, employee training, employee time to look after the collection and other factors required for the safe placement, packaging and shipment of fluorescent lamps to a recycler. An obstacle also exists in that it requires time to build solid relationships with retail stores that would allow for this collection. Both Indiana and Minnesota were able to build successful programs only after taking time to meet face to face with retail stores. Another aspect that the northwest lacks is government regulation to promote take back. Minnesota has implemented a ban on fluorescent lamps in municipal solid waste, which forces residents to pay to recycle at hardware stores or at household hazardous waste facilities.

A curbside collection program has been suggested as one option for CFL collection. It does not appear to have any precedent in other areas. The benefits of this are that it is very convenient to recycle CFLs for those who have curbside recycling programs. It requires no trips and combines the recycling of CFLs with recycling other materials. Curbside programs also have a good degree of population coverage in Oregon. 95% of towns with populations above 4,000 people in Oregon have curbside recycling collection. That covers most cities in the Willamette Valley where a majority of CFLs are likely to be located. It is possible that a municipality would be willing to try a pilot program with the garbage and recycling franchise that serves their city. One potential benefit of curbside collection is that the cost of the program could be built in to the garbage billing. This would avoid the disincentive of having to pay a separate fee for disposal.

There are drawbacks to curbside recycling as well. Collecting fees through the garbage handlers would require raising rates. Since garbage collection in Oregon is a franchised industry, this would require the approval of the agency that grants the franchises. The process of having the curbside trucks pick up CFLs would require more space on already full trucks and would add an item that requires special handling. This would interfere with the efficiency of sorting processes that are in place. There has been a recent trend in curbside recycling to commingle and adding CFLs as a special collection item runs counter to that trend. There is an additional problem of trying to ensure that the CFLs remain in tact while being set out by the household and handled by the recycler. The collection industry has also raised concerns about liability in collecting and handling CFLs. The scalability of the curbside recycling is another drawback. A desire for this program was to have it be easily replicable in other areas, and Oregon likely has a better curbside recycling infrastructure than other states.

Another CFL recycling option focuses on household hazardous waste collection events and facilities. There are multiple ideas to increase CFL recycling within this option. It could be expanded HHW collection events by DEQ or waste districts, additional collection points for specific types of HHW or an educational campaign to inform people where they can recycle their CFLs. The theme connecting these ideas is using existing HHW collection to get more CFLs recycled through this channel. The advantage to this is that it utilizes existing programs and infrastructure. There are permanent household hazardous waste facilities in Portland and Eugene, a lamp collection site at a landfill in Salem, and special DEQ collection events serve many parts of rural Oregon. This option is possibly the most expedient of all options because it may be as simple as an educational campaign that encourages people to take CFLs to their HHW facility or event.

One major disadvantage to this option is that HHW facilities and events are not convenient for most people. Even though they are located in the cities of the largest populations they are still not convenient for many that live within those cities. The lack of convenience combined with lack of public knowledge about CFL recycling is probably related to the low numbers of CFLs seen at collection sites. The expansion of collection points or events may require larger drivers than CFL collection. It would be difficult to add HHW collection capacity or events just for the purpose of collecting CFLs. Another drawback is that for collection events households must store and then remember to take their CFLs during the events. For many places the collection events are once each year, which would require households to store burnt out lamps for a considerable time.

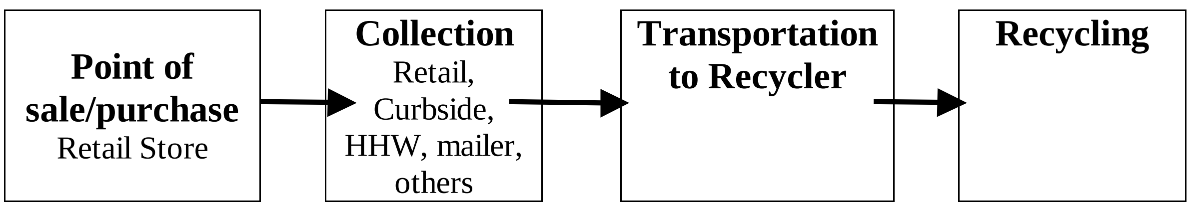
One final option is using mailers to return burnt out CFLs. This idea is the reverse of what PacifiCorp did to distribute CFLs to their customers. The basic concept is that mailers would be distributed to households. When a CFL burnt out it would go in the mailer and be sent to a lamp recycler. One positive aspect of this is that it requires no trips by the household to recycle the CFL. It would also guarantee complete coverage for all areas of the state. It may also be advantageous to the lamp recycler since the lamps travel directly to them. There are also some large obstacles for this option to overcome. It involves shipping a breakable and hazardous product by mail. The issue of how to distribute the mailers is another issue. The cost of mailing each bulb individually may also be high, though this could be partially offset by reduced transportation costs to the lamp recycler. Unless the mailers could be reused, it seems that there would be a large amount of packaging waste associated with this option. This option would also require a stable and ongoing system to distribute mailers.

These options are not mutually exclusive and it may be advantageous to combine some as part of an overall lamp recycling effort. For example, it may be best to concentrate the efforts involved with engaging multiple retail stores in a metropolitan area where there are likely to be a higher number of CFLs to collect. An option that involves increased education about CFL waste and collection events may be more appropriate for rural areas. In a pilot program it could be tested whether curbside collection is as effective as retail collection in cities of similar size such as Salem and Eugene.

Payment Options

The collection of CFLs is one part of program design to be considered. Another major part is the transfer of funds to pay for the recycling. Table 5 shows an outline of the materials flow and payment options for the costs of the recycling program. These costs are the recycling fees and may also include education and advertisement about the program and any administrative costs to running the program.

CFL Product Flow



Payment Options

Type of Payment	Who pays?	Collected by…	When?
Taxes	Tax payer	Government	Tax payment time
Producer Paid	Producer	1) Government 2) Industry Association	1) Time of sale 2) Time of collection 3) Time of recycling
Advanced Deposit Fee	CFL purchasers	Retailer	Time of purchase
Advanced Deposit Fee w/partial refund	CFL purchasers	Retailer	Time of Purchase
End of Life Fee	CFL purchasers	1) Retail store 2) Drop off point	End of life
Waste Hauler	Waste ratepayers	Garbage bill/collector	Monthly
Utility supported	Utility (partial?)	1) Government 2) Industry Association 3) Recyclers	Monthly, quarterly

Table 5 – Outline of payment options

Under the first option, payment is made through taxes and collected by the government. In this simplified model of tax collection the government would ultimately pay the costs of the recycling program. In the second option the producer of the CFL pays to have the CFLs recycled at the end of life. The producers pay the government, which then administers the funds, or pays into an industry association that administers the funds. The producers could pay either based on the number of sales, the number of CFLs collected for recycling, or the CFLs that are actually recycled. Both the advance deposit fee and the advance deposit fee with partial refund rely on the CFL purchaser to pay a fee at the time of purchase. This fee is then collected by the retailer and put into a fund to pay for lamp recycling. The partial refund model allows the consumer to collect a refund when the lamp is recycled, similar to the bottle bill. The fifth option is for the CFL user to pay for lamp disposal at the end of life. The fee is collected wherever the consumer drops off the bulb for recycling. This is similar to how Minnesota's program is structured with the addition of a utility subsidy to offset the recycling fee. In the sixth option, waste haulers are responsible for collection of the CFLs. The ratepayers would pay an extra amount on their monthly bill to cover the costs of recycling and costs incurred by the hauler. The final option is utility support for the program. As in Minnesota, the utility supports part of the program cost and can pay either to the government, industry associations or recyclers directly. As with the collection options, the payment options can be combined so that multiple parties can support the overall cost of the program.

Estimated program costs

The three major cost components to the program will likely be the cost of recycling the lamps, the educational and advertising component and the administrative costs. The costs of recycling are based on the model that projects the number of CFLs that are expected to burn out each year in the northwest region. The other two factors are the cost per lamp to recycle and the percentage of lamps recovered. Lamp recyclers interviewed for the program were all fairly consistent about the estimation of the recycling cost per lamp. These cost typically included costs such as transportation, any containers provided and insurance. There was a range of $0.35/lamp on the low end of the scale and up to $1.00/on the high end. This range depended somewhat on what type of CFL was being recycled. For the estimates used here are $0.40/lamp as the low, $0.60/lamp as the middle and $0.80/lamp as the high. The costs were then broken out by the fraction of bulbs recovered of the total number projected to burn out each year. Estimates are shown for 25% recovery, 50% recovery and 75% recovery. These estimates are shown in Table 6. This data is presented graphically in Figure 2.

Recycling Costs Assuming 25% Recovery Rate

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
# of Lamps	423,571	452,345	561,645	605,007	622,543	312,050	249,950	249,950	249,950	249,950
Low ($0.40)	$ 169,428	$ 180,938	$ 224,658	$ 242,003	$ 249,017	$ 124,820	$ 99,980	$ 99,980	$ 99,980	$ 99,980
Middle ($0.60)	$ 254,142	$ 271,407	$ 336,987	$ 363,004	$ 373,526	$ 187,230	$ 149,970	$ 149,970	$ 149,970	$ 149,970
High ($0.80)	$ 338,856	$ 361,876	$ 449,316	$ 484,006	$ 498,034	$ 249,640	$ 199,960	$ 199,960	$ 199,960	$ 199,960

Recycling Costs Assuming a 50% Recovery Rate

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
# of Lamps	847,141	904,691	1,123,289	1,210,014	1,245,085	624,100	499,900	499,900	499,900	499,900
Low ($0.40)	$ 338,856	$ 361,876	$ 449,316	$ 484,006	$ 498,034	$ 249,640	$ 199,960	$ 199,960	$ 199,960	$ 199,960
Middle ($0.60)	$ 508,285	$ 542,814	$ 673,974	$ 726,008	$ 747,051	$ 374,460	$ 299,940	$ 299,940	$ 299,940	$ 299,940
High ($0.80)	$ 677,713	$ 723,753	$ 898,631	$ 968,011	$ 996,068	$ 499,280	$ 399,920	$ 399,920	$ 399,920	$ 399,920

Recycling Costs Assuming a 75% Recovery Rate

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
# of Lamps	1,270,712	1,357,036	1,684,934	1,815,021	1,867,628	936,150	749,850	749,850	749,850	749,850
Low ($0.40)	$ 508,285	$ 542,814	$ 673,974	$ 726,008	$ 747,051	$ 374,460	$ 299,940	$ 299,940	$ 299,940	$ 299,940
Middle ($0.60)	$ 762,427	$ 814,222	$ 1,010,960	$ 1,089,013	$ 1,120,577	$ 561,690	$ 449,910	$ 449,910	$ 449,910	$ 449,910
High ($0.80)	$ 1,016,569	$ 1,085,629	$ 1,347,947	$ 1,452,017	$ 1,494,102	$ 748,920	$ 599,880	$ 599,880	$ 599,880	$ 599,880

Table 6 -Estimates of CFL recycling costs

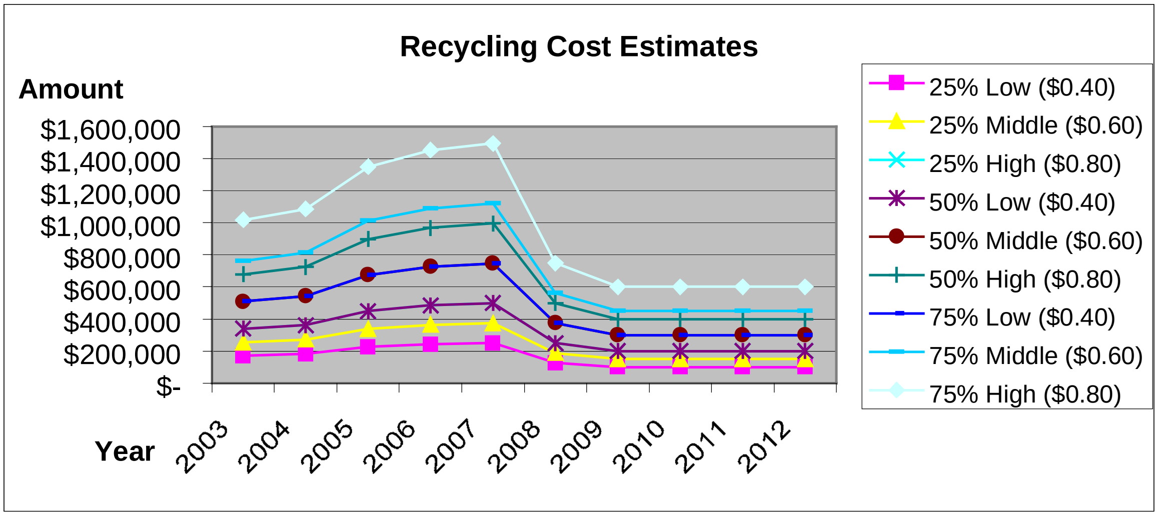


Figure 2 – Cost of lamp recycling per year

The estimates for the advertising and administrative costs of the program are more difficult to judge. In Minnesota, Xcel Energy estimated that they pay about $300,000 per year to recycle 150,000 lamps. The recycling fee paid to Mercury Technologies by Xcel is $5,000. Xcel said that a vast majority of their program budget went to pay for advertising and other program costs. These numbers do not match the coupon cost of $0.50 per bulb, but Xcel could not be reached for clarification as of this report's release. In Indiana the program has been funded by grants. The first grant was for $30,000 over 4 years, or $7,500 per year. This cost was supposed to cover 75% of advertising and recycling, so it can be calculated that the program budget was $10,000 year. This was when there was only one Sears store in the program. The program's expansion is funded by a 2-year grant for $40,000. This grant pays for half of the cost of the program, so it can be calculated that the program now has a budget of $40,000/year. Early on in the program about 13,200 4-foot tubes were recycled at a cost of $0.26/tube and an $800/load transportation fee. The cost of recycling would be about $5,800, assuming 3 trips per year. It is difficult to extrapolate what the non-recycling costs of a program in the northwest would be.

Conclusion

With the information and data presented in this report, it is hoped that Phase II of the CFL Recycling Project can begin. The report is intended to serve as a reference document for the discussions of how to set up a CFL recycling program in Oregon. It is probable that the members of Phase II of the project may request more information or additional research for the process. Additional research will be added to this report as the discussions progress.

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Appendix A: Table of CFL Disposal Estimates for the Northwest

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Number of CFLs sold	204,000	237,233	324,431	578,980	8,454,803	2,500,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Total Expected to burn out	25,500	55,154	95,708	168,081	1,233,417	1,555,786	1,694,282	1,809,382	2,246,578	2,420,028	2,490,170	1,248,200	999,800	999,800	999,800	999,800
Burnouts in each year																
1997	25,500	25,500	25,500	25,500	33,986	33,986	33,986									
1998		29,654	29,654	29,654	29,654	39,523	39,523	39,523								
1999			40,554	40,554	40,554	40,554	54,050	54,050	54,050							
2000				72,373	72,373	72,373	72,373	96,458	96,458	96,458						
2001					1,056,850	1,056,850	1,056,850	1,056,850	1,408,570	1,408,570	1,408,570					
2002						312,500	312,500	312,500	312,500	415,000	415,000	415,000				
2003							125,000	125,000	125,000	125,000	166,600	166,600	166,600			
2004								125,000	125,000	125,000	125,000	166,600	166,600	166,600		
2005									125,000	125,000	125,000	125,000	166,600	166,600	166,600	
2006										125,000	125,000	125,000	125,000	166,600	166,600	166,600
2007											125,000	125,000	125,000	125,000	166,600	166,600
2008												125,000	125,000	125,000	125,000	166,600
2009													125,000	125,000	125,000	125,000
2010														125,000	125,000	125,000
2011															125,000	125,000
2012																125,000

Appendix B
Compact Fluorescent Lamp Recycling Project Objectives

The participants of the Compact Fluorescent Lamp (CFL) Recycling Project are a group of organizations that include electric utilities, private businesses, government agencies, industry associations and non-profit groups. The participants are committed to developing a pilot project in Oregon to test CFL collection and recycling methods with the intent that it will lead to a sustained recycling system. This is intended to be a public process that is open to additional groups that wish to join. The members of this group agree to the following objectives to guide the design and implementation of such a system:

Project Objectives:

- **Environmental Protection:** Primary goal is to avoid mercury buildup in the environment associated with the use of CFLs. A specific project goal is to avoid mercury emission during the collection, transportation and recycling of the CFLs.
- **Easy Access:** The recycling system should allow the public to easily recycle their CFLs by providing the most convenient recycling opportunities possible
- **Low Cost:** The costs of the recycling system, such as collection, transportation and recycling, should be minimized.
- **Fair Cost Allocation:** The costs of the recycling system should be allocated fairly so as to minimize impacts to manufacturers, retailers, waste handlers, state and local government and other involved in the collection, transportation and recycling of CFLs.
- **Compliance:** The recycling program must provide for compliance with all applicable regulations, such as RCRA, CERCLA, state solid waste regulations and the Universal Waste Rule.
- **Education:** Education and public outreach are vital components of a successful CFL recycle program. They should point out that CFLs are safe in the home and provide an overall environmental benefit, but if not handled and recycled properly can create environmental and human health impacts.
- **Replicable:** To the extent possible, the program will be designed so that after its implementation in Oregon, it can be easily replicated in other areas, especially in the Western United States.
- **Expandable:** CFLs are only one of several sources of potential mercury emissions. To the extent possible, this program should be expandable so that it may later include the collection and recycling of other mercury bearing items, including increased recycling levels for fluorescent light tubes.
- **Recycling System:** The participants are committed to developing a pilot project to test CFL collection and recycling methods with the intent that it will lead to a sustained recycling system.
- **Sustainable:** the group as a whole should design the system so that it can sustain itself without ongoing involvement.

Compact Fluorescent Lamp Recycling Program Timeline

Activity		Week																				
		9/9	9/16	9/23	9/30	10/7	10/14	10/21	10/28	11/4	11/11	11/18	11/25	12/2	12/9	12/16	12/23	12/30	1/6	1/13	1/20	1/27
Phase I																						
	Completed																					
Phase II																						
A	Contact organizations for OR CFL Stewardship Team																					
B	Coordinate meetings																					
	Mtg 1 – Present program models																					
	Mtg 2 – Choose pilot project																					
	Mtg 3 – Final meeting																**Holidays**					
C	Draft final pilot guidelines																					
	Coordinate pilot project launch																					